CALIFORNIA ENERGY COMMISSION

2001 UPDATE

ASSEMBLY BILL 970 DRAFT NONRESIDENTIAL BUILDING ENERGY EFFICIENCY STANDARDS

CONTRACTOR'S REPORT

VOLUME 3 - DRAFT ACM MANUAL

November 2000
P400-00-025/ V3

Gray Davis, *Governor*

CALIFORNIA ENERGY COMMISSION

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Contractor Report

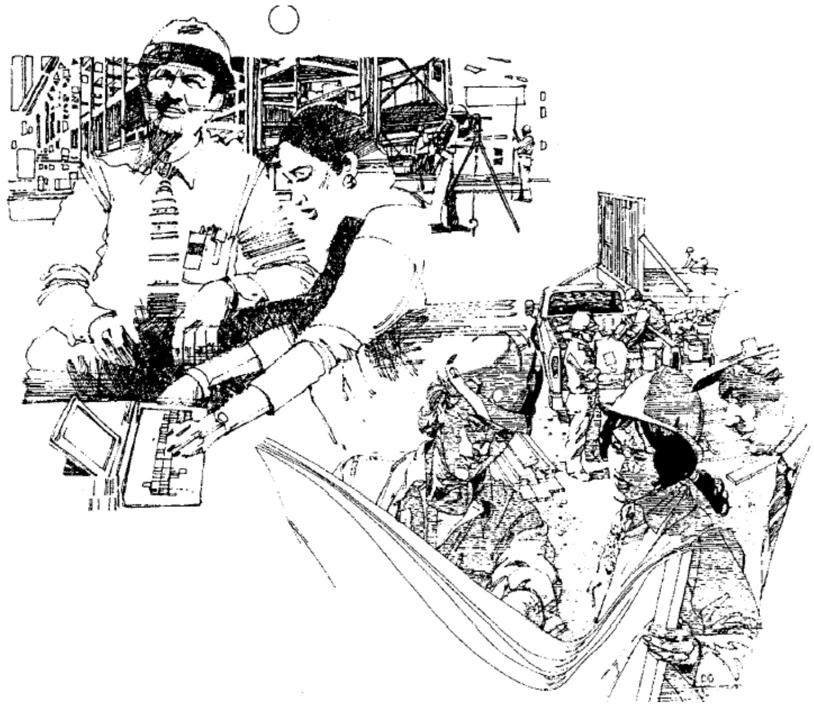
2001 Update – AB 970 Draft Nonresidential Building Standards

Energy Commission Publication No. P 400-00-025/V3

Draft ACM Manual

This Contractor Report, prepared by Eley Associates, contains the Draft ACM Manual, which has the rules for making whole building performance calculations for code compliance. This report is intended for discussion at an Efficiency Standards Committee hearing on November 28, 2000. The hearing purpose is to obtain public comment on this report and revisions to the Title 24 Building Energy Efficiency Standards (California Code of Regulations, Title 24, Part 6).

November 17, 2000



Volume III – Draft ACM Manual

Assembly Bill 970 Emergency Rulemaking –
2001 Update of California
Nonresidential Energy Standards

November 17, 2000

California Energy Commission
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Task 6 – Draft ACM Manual

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Introduction

This document is Volume III of a project to update the California nonresidential building energy efficiency standards. The project is developing upgrades and improvements in an emergency rulemaking dictated by the California legislature through Assembly Bill 970. The potential upgrades are mostly based on the national standard, ASHRAE/IESNA Standard 90.1-1999 (ASHRAE 1999), which was recently adopted and approved as an ANSI national consensus standard.

The research is organized in four volumes. Volume I is the measure analysis report, which contains the life cycle cost to justify the requirements. Volume II is the Draft Standard and contains underlines and strikethroughs to the regulation. This Volume III is the Draft ACM Manual, which has the rules for making whole building performance calculations for code compliance. Volume IV is an Impact Analysis that estimates statewide gas and electricity savings that will result from the proposed changes.

Cool Roofs

2.2.1.4 Absorptance

Description: The fraction of the incident solar radiation absorbed as heat on the construction assembly's opaque exterior surface.

DOE Keyword: ABSORPTANCE

Input Type: Default

Tradeoffs: ~~Neutral~~Yes

Modeling Rules for Proposed Design: ~~The ACM must either receive use user input for the absorptance of each opaque exterior surface or use the default value.~~
For roofs, qualifying cool roofs shall model an absorptance of 0.45. All other roofs shall use the default value.
For other opaque surfaces, the ACM must either receive user input for the absorptance of each opaque exterior surface or use the default value.
~~value.~~

Cool Roof Value: Roof = 0.45

To qualify as a cool roof the roof must meet the requirements of Section 119.5 of the Standard, which states:

(a) Effective January 1, 2003, a roof shall be considered a cool roof if the roof is certified and labelled according to requirements of Section 10-113 and if the roof meets conditions (1) or (2) below. Prior to January 1, 2003, manufacturer's published performance data shall be acceptable to show compliance with one of the following conditions.

(1) Roof of concrete tile (per ASTM C55-99) and clay tile (per ASTM C1167-96) require a minimum initial total solar reflectance of 0.40 when tested in accordance with ASTM E903 or E1918, and a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408.

(2) All other roofs require a minimum initial total solar reflectance of 0.70 when tested in accordance with ASTM E903 or E1918, and a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408.

Default:	Roof	= 0.70
	Exterior wall	= 0.70
	Demising wall	= 0.05
Low Value:	Exterior wall	= 0.20
	Demising wall	= 0.02
High Value:	Exterior wall	= 0.90

Demising wall = 0.80

Cool Roof Caution Warning on PERF-1 if a cool roof credit is claimed.

Low Caution: Warning on PERF-1 that the absorptance of an exterior wall is less than 0.50

Modeling Rules for Reference Design (All): ~~For the reference method, the absorptance of each opaque exterior surface is the same as the proposed design.~~
For the reference method, the roof absorptance shall be modeled at 0.70. The absorptance of each other opaque exterior surface is the same as the proposed design.

2.2.1.5 Surface Emissivity

Description: The ratio of radiation intensity from the construction assembly's opaque exterior surface to the radiation intensity at the same wavelength from a blackbody at the same temperature.

DOE Keyword: OUTSIDE-EMISS

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The proposed design shall model a surface emissivity of 0.90.

Modeling Rules for Reference Design (All): The surface emissivity of the reference design shall be the same as the surface emissivity of the proposed design.

Fenestration

2.2.2.14.2 Fenestration Thermal Properties

Description: ACMs shall model the overall U-value and Solar Heat Gain Coefficient (SHGC) for each fenestration assembly, including inside and outside air films and effects of framing, spacers and other non-glass materials as applied to the full rough-out fenestration area. For manufactured fenestration assemblies, the overall U-value and SHGC are from the NFRC label attached to the assembly or from default values listed in Tables 1-D and 1-E of the Standards.

For ~~each~~ field-fabricated fenestration ~~assembly~~assemblies in buildings 100,000 ft² or larger, ACMs must allow the user to *either* input the default U-~~value~~ factor and SHGC listed in Tables 1-D and 1-E or use NFRC ratings for field-fabricated systems. For buildings smaller than 100,000 ft², the user can either NFRC ratings for field-fabricated systems ~~of the Standards~~ *or* calculate the assembly's U-value and SHGC using a method approved by the Commission.

In this Section the word "Window" is used to refer to fenestration. A horizontal window with a tilt of up to 60 degrees from the horizontal is a skylight.

DOE Keyword: FRAME-CONDUCTANCE
FRAME-WIDTH
FRAME-ABS

Input Type: Required
Tradeoffs: Yes

Modeling Rules for Proposed Design: For manufactured windows, ACMs must require the user to input the U-value and SHGC for each window from the NFRC label as it occurs in the construction documents for the building.

For field-fabricated windows in buildings 100,000 ft² or larger, ACMs must either use the default U-~~value~~ factor and SHGC listed in Tables 1-D and 1-E of the Standards *or* ~~calculate the overall U-value and SHGC using a method approved by the Commission.~~use NFRC ratings for field fabricated systems.

For field-fabricated windows in buildings less than 100,000 ft², ACMs must determine the U-factor and SHGC using procedures and defaults specified in Appendix I; use NFRC ratings for field fabricated systems; *or* calculate the overall U-value and SHGC using a method approved by the Commission.

For skylights, ACMs must determine the U-factor and SHGC using procedures and defaults specified in Appendix I; use NFRC ratings for field fabricated systems; *or* calculate the overall U-value and SHGC using a method approved by the Commission.

The reference program uses a FRAME ABSORPTANCE of 0.70.

Modeling Rules for Reference Design (New & Altered Existing): ACMs shall use the appropriate "Maximum U-value" and RSHG or SHGC for the window as appropriate from Tables 1-H and 1-I of the Standards including the framing according to the occupancy type and the climate zone. The reference design uses a FRAME ABSORPTANCE of 0.70.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall use the existing design's U-value and SHGC or RSHG as appropriate including the framing. The reference design uses a FRAME ABSORPTANCE of 0.70.

2.2.2.14.5 Solar Heat Gain Coefficient of Fenestration in Walls & Doors

Description: The reference method models the solar heat gain coefficient (SHGC) of glass including the framing, dividers, and mullions. The shading effects of dirt, dust, and degradation are purposely neglected and an ACM user may not adjust solar heat gain coefficients because of these effects. The ACM user's manual must reflect these restrictions on user entries.

If the user has specified Display Perimeter, ACMs may also receive an input in a subordinate menu for the Relative Solar Heat Gain (RSHG) requirement except for cases where local building codes prohibit or limit the use of overhangs or exterior shading devices. The use of this RSHG exception input is itself an exceptional condition that must be reported in the exceptional conditions checklist of the PERF-1 form.

DOE Keyword: SHADING-COEF

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: Fenestration solar heat gain coefficient (SHGC) for each fenestration surface shall be input as it occurs in the construction documents for the building. ACMs that require inputting shading coefficient (SC) instead of SHGC shall calculate the fenestration’s shading coefficient using the following formula:

$$SC_{fenestration} = SHGC/0.87$$

Note: This equation is taken from Blueprint #57, dated Fall 1996. Since both SC for nonresidential buildings and SHGC apply to the entire rough-out opening, the adjustment for framing and divider has been removed.

Modeling Rules for Reference Design (New & Altered Existing): ACMs shall use the appropriate maximum RSHG values from Tables 1-H and 1-I of the Standards according to occupancy, climate zone and orientation as the standard design solar heat gain coefficient. The maximum RSHG is different for north-oriented glass; for the purposes of establishing standard design solar heat gain coefficient, north glass is glass in walls facing from 45^{o} west (not inclusive) to 45^{o} east (inclusive) of true north.

If the user has claimed the RSHG exception for a section of display perimeter, the standard design uses the maximum RSHG for north glass found in Tables 1-H and 1-I of the Standards for any fenestration surface utilizing this exception.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall use the same RSHG value as the existing design including the framing.

Appendix I – Default Fenestration Thermal Properties

Solar Heat Gain Coefficient (SHGC)

The preferred way to determine SHGC is through the use of NFRC 200. As an alternative, however, SHGC may be calculated using the following equation.

$$SHGC = 0.08 + 0.86 \times SHGC_c$$

where

SHGCc is the center of glass solar heat gain coefficient for the glass alone

SHGC is the solar heat gain coefficient for the fenestration including glass and frame

The basis of this equation is a CEC Staff Report, Alternative Calculation Method for Nonresidential Solar Heat Gain Coefficient (P400-00-011), July 2000.

Thermal Transmittance (U-factor)

Table I-1 provides default U-factors for skylights and site-built fenestration in buildings covered by the Nonresidential Energy Standards. The default table may only be used for:

- Field-fabricated glazed wall systems in buildings covered by the Nonresidential Energy Standards that have a gross conditioned floor area less than 100,000 ft^2.
- Skylights in buildings covered by the Nonresidential Energy Standards.

The default Table I-1 is consistent with default U-factors published in Table 5, Chapter 29, ASHRAE Fundamentals Handbook, 1997, which is referenced in the Energy Standards.

Table I-1 – Assembly U-Factors for Unlabeled Glazed Wall Systems (Site-Built Windows) and Unlabeled Skylights

Product Type		**Vertical Installation** — **Unlabeled Glazed Wall Systems (Site Built Windows)** (include site assembled fixed windows only, does not include operable windows)				**Sloped Installation** — **Unlabeled Skylight with Curb** (includes glass/plastic, flat/domed, fixed/operable)				**Sloped Installation** — **Unlabeled Skylight without Curb** (includes glass/plastic, flat/domed, fixed/operable)		
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Wood/Vinyl	Structural Glazing	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	**Glazing Type**											
	Single Glazing											
1	1/8" glass	1.22	1.11	0.98	1.11	1.98	1.89	1.75	1.47	1.36	1.25	1.25
2	1/4" acrylic/polycarb	1.08	0.96	0.84	0.96	1.82	1.73	1.60	1.31	1.21	1.10	1.10
3	1/8" acrylic/polycarb	1.15	1.04	0.91	1.04	1.90	1.81	1.68	1.39	1.29	1.18	1.18
	Double Glazing											
4	1/4" airspace	0.79	0.68	0.56	0.63	1.31	1.11	1.05	0.84	0.82	0.70	0.66
5	1/2" airspace	0.73	0.62	0.50	0.57	1.30	1.10	1.04	0.84	0.81	0.69	0.65
6	1/4" argon space	0.75	0.64	0.52	0.60	1.27	1.07	1.00	0.80	0.77	0.66	0.62
7	1/2" argon space	0.70	0.59	0.48	0.55	1.27	1.07	1.00	0.80	0.77	0.66	0.62
	Double Glazing, *e*=0.60 on surface 2 or 3											
8	1/4" airspace	0.76	0.65	0.53	0.61	1.27	1.08	1.01	0.81	0.78	0.67	0.63
9	1/2" airspace	0.69	0.58	0.47	0.54	1.27	1.07	1.00	0.80	0.77	0.66	0.62
10	1/4" argon space	0.72	0.61	0.49	0.56	1.23	1.03	0.97	0.76	0.74	0.63	0.58
11	1/2" argon space	0.67	0.56	0.44	0.51	1.23	1.03	0.97	0.76	0.74	0.63	0.58
	Double Glazing, *e*=0.40 on surface 2 or 3											
12	1/4" airspace	0.74	0.63	0.51	0.58	1.25	1.05	0.99	0.78	0.76	0.64	0.60
13	1/2" airspace	0.66	0.55	0.44	0.51	1.24	1.04	0.98	0.77	0.75	0.64	0.59
14	1/4" argon space	0.69	0.57	0.46	0.53	1.18	0.99	0.92	0.72	0.70	0.58	0.54
15	1/2" argon space	0.63	0.51	0.40	0.47	1.20	1.00	0.94	0.74	0.71	0.60	0.56
	Double Glazing, *e*=0.20 on surface 2 or 3											
16	1/4" airspace	0.70	0.59	0.48	0.55	1.20	1.00	0.94	0.74	0.71	0.60	0.56
17	1/2" airspace	0.62	0.51	0.39	0.46	1.20	1.00	0.94	0.74	0.71	0.60	0.56
18	1/4" argon space	0.64	0.53	0.42	0.49	1.14	0.94	0.88	0.68	0.65	0.54	0.50
19	1/2" argon space	0.57	0.46	0.35	0.42	1.15	0.95	0.89	0.68	0.66	0.55	0.51
	Double Glazing, *e*=0.10 on surface 2 or 3											
20	1/4" airspace	0.68	0.57	0.45	0.52	1.18	0.99	0.92	0.72	0.70	0.58	0.54
21	1/2" airspace	0.59	0.48	0.37	0.44	1.18	0.99	0.92	0.72	0.70	0.58	0.54
22	1/4" argon space	0.62	0.51	0.39	0.46	1.11	0.91	0.85	0.65	0.63	0.52	0.47
23	1/2" argon space	0.55	0.44	0.33	0.39	1.13	0.93	0.87	0.67	0.65	0.53	0.49

Product Type	**Vertical Installation** — **Unlabeled Glazed Wall Systems (Site Built Windows)** (include site assembled fixed windows only, does not include operable windows)	**Sloped Installation** — **Unlabeled Skylight with Curb** (includes glass/plastic, flat/domed, fixed/operable)	**Sloped Installation** — **Unlabeled Skylight without Curb** (includes glass/plastic, flat/domed, fixed/operable)

Product Type		Vertical Installation				Sloped Installation						
		Unlabeled Glazed Wall Systems (Site Built Windows) (include site assembled fixed windows only, does not include operable windows)				Unlabeled Skylight with Curb (includes glass/plastic, flat/domed, fixed/operable)				Unlabeled Skylight without Curb (includes glass/plastic, flat/domed, fixed/operable)		
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Wood/Vinyl	Structural Glazing	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Wood/Vinyl	Structural Glazing	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	Glazing Type											
	Double Glazing, *e*=0.05 on surface 2 or 3											
24	1/4" airspace	0.67	0.56	0.44	0.51	1.17	0.97	0.91	0.70	0.68	0.57	0.52
25	1/2" airspace	0.57	0.46	0.35	0.42	1.17	0.98	0.91	0.71	0.69	0.58	0.53
26	1/4" argon space	0.60	0.49	0.38	0.44	1.09	0.89	0.83	0.63	0.61	0.50	0.45
27	1/2" argon space	0.53	0.42	0.31	0.38	1.11	0.91	0.85	0.65	0.63	0.52	0.47
	Triple Glazing											
28	1/4" airspaces	0.63	0.52	0.41	0.47	1.12	0.89	0.84	0.64	0.64	0.53	0.48
29	1/2" airspaces	0.57	0.46	0.35	0.41	1.10	0.87	0.81	0.61	0.62	0.51	0.45
30	1/4" argon spaces	0.60	0.49	0.38	0.43	1.09	0.86	0.80	0.60	0.61	0.50	0.44
31	1/2" argon spaces	0.55	0.45	0.34	0.39	1.07	0.84	0.79	0.59	0.59	0.48	0.42
	Triple Glazing, *e*=0.20 on surface 2,3,4, or 5											
32	1/4" airspaces	0.59	0.48	0.37	0.42	1.08	0.85	0.79	0.59	0.60	0.49	0.43
33	1/2" airspaces	0.52	0.41	0.30	0.35	1.05	0.82	0.77	0.57	0.57	0.46	0.41
34	1/4" argon spaces	0.54	0.44	0.33	0.38	1.02	0.79	0.74	0.54	0.55	0.44	0.38
35	1/2" argon spaces	0.49	0.38	0.28	0.33	1.01	0.78	0.73	0.53	0.54	0.43	0.37
	Triple Glazing, *e*=0.20 on surfaces 2 or 3 and 4 or 5											
36	1/4" airspaces	0.55	0.45	0.34	0.39	1.03	0.80	0.75	0.55	0.56	0.45	0.39
37	1/2" airspaces	0.48	0.37	0.26	0.31	1.01	0.78	0.73	0.53	0.54	0.43	0.37
38	1/4" argon spaces	0.50	0.39	0.29	0.34	0.99	0.75	0.70	0.50	0.51	0.40	0.35
39	1/2" argon spaces	0.45	0.34	0.24	0.29	0.97	0.74	0.69	0.49	0.50	0.39	0.33
	Triple Glazing, *e*=0.10 on surfaces 2 or 3 and 4 or 5											
40	1/4" airspaces	0.54	0.43	0.32	0.37	1.01	0.78	0.73	0.53	0.54	0.43	0.37
41	1/2" airspaces	0.46	0.35	0.25	0.29	0.99	0.76	0.71	0.51	0.52	0.41	0.36
42	1/4" argon spaces	0.48	0.38	0.27	0.32	0.96	0.73	0.68	0.48	0.49	0.38	0.32
43	1/2" argon spaces	0.42	0.32	0.21	0.26	0.95	0.72	0.67	0.47	0.48	0.37	0.31
	Quadruple Glazing, *e*=0.10 on surfaces 2 or 3 and 4 or 5											
44	1/4" airspaces	0.49	0.38	0.28	0.33	0.97	0.74	0.69	0.49	0.50	0.39	0.33
45	1/2" airspaces	0.43	0.32	0.22	0.27	0.94	0.71	0.66	0.46	0.47	0.36	0.30
46	1/4" argon spaces	0.45	0.34	0.24	0.29	0.93	0.70	0.65	0.45	0.46	0.35	0.30
47	1/2" argon spaces	0.41	0.30	0.20	0.24	0.91	0.68	0.63	0.43	0.44	0.33	0.28
48	1/4" krypton spaces	0.41	0.30	0.20	0.24	0.88	0.65	0.60	0.40	0.42	0.31	0.25

Lighting

2.3.1 Occupancy Assignment

Table 2-1: Occupancy Assumptions When Lighting Plans are Submitted for the Entire Building or When Lighting Compliance is not Performed

Occupancy Type	#people 1000SF(1)	Sensible person(2)	Latent person(2)	Recept. W/SF(3)	Water Btuh person	Lighting W/SF(4)	CFM SF(5)
Commercial and Industrial Storage	5	268	403	0.43	108	0.7	0.15
Grocery Store	29	252	225	0.91	113	1.5	0.23
General Commercial and Industrial Work, High Bay	7	375	625	1.0	120	1.2	0.15
General Commercial and Industrial Work, Low Bay	7	375	625	1.0	120	1.0	0.15
Medical/Clinical	10	250	213	1.18	110	1.2	0.15
Office	10	250	206	1.34	106	1.2	0.15
Other	10	250	200	1.0	120	0.6	0.15
Religious Worship, Auditorium~~, Convention~~	136	245	112	0.96	57	1.8	1.03
Convention	136	245	112	0.96	57	1.4	1.03
Restaurant	45	274	334	0.79	366	1.2	0.38
Retail and Wholesale Store	29	252	224	0.94	116	1.7	0.23
School	40	246	171	1.0	108	1.4	0.32
Theater	130	268	403	0.54	60	1.3	0.98
Unknown	10	250	200	1.0	120	1.2	0.15

(1) Most occupancy values are based on an assumed mix of suboccupancies within the area. These values were taken from the 1994 Uniform Building Code, Table No. 10-A. Full value for design conditions. Full year operational schedules reduce these values by up to 50% for compliance simulations and full year test simulations.

(2) From Table 3, p. 28.8, ASHRAE 1997 Handbook of Fundamentals

(3) From Lawrence Berkeley Laboratory study. This value is fixed and includes all equipment that are plugged into receptacle outlets.

(4) From Table 1-M of the Standards for the applicable occupancy.

(5) Developed from Section 121 and Table 1-F of the Standards.

Table 2-2: Area Occupancy Assumptions When Lighting Plans are Submitted for Portions or for the Entire Building or When Lighting Compliance is not Performed

Sub-Occupancy Type (1)	#people 1000 SF(2)	Sensible person(3)	Latent person(3)	Recept. W/SF(4)	Water Btuh person	Lighting W/SF(5)	CFM SF(6)
All Others	10	250	200	1.0	120	0.6	0.15
Auditorium	143	245	105	1.0	60	2.0	1.07
Auto Repair Workshop	10	275	475	1.0	120	1.2	1.50
Bank/Financial Institution	10	250	250	1.5	120	1.4	0.15
Bar, Cocktail Lounge and Casino	67	275	275	1.0	120	1.1	1.50
Barber and Beauty Shop	10	250	200	2.0	120	1.0	0.40
Classroom	50	245	155	1.0	120	1.6	0.38
Courtrooms	25	250	200	1.5	120	1.1	0.19
Commercial/Industrial Storage	3	275	475	0.2	120	0.6	0.15
Commercial/Industrial Work-General, High Bay	10	275	475	1.0	120	1.2	0.15
Commercial/Industrial Work-General, Low Bay	10	275	475	1.0	120	1.0	0.15
Commercial/Industrial Work-Precision (8)	10	250	200	1.0	120	1.5	0.15
Convention, Conference and Meeting Center	67	245	155	1.0	60	~~1.6~~1.5	0.50
Corridor, Restroom, and Support Area	10	250	250	0.2	0	0.6	0.15
Dining Area	67	275	275	0.5	385	1.1	0.50
Dry Cleaning (Coin Operated)	10	250	250	3.0	120	1.0	0.30
Dry Cleaning (Full Service Commercial)	10	250	250	3.0	120	1.0	0.45
Electrical and Mechanical Room	3	250	250	0.2	0	0.7	0.15
Exercising Centers and Gymnasium	20	255	875	0.5	120	1.0	0.15
Exhibit Display Area and Museum	67	250	250	1.5	60	2.0	0.50
Grocery Sales Area	33	250	200	1.0	120	1.6	0.25
High-Rise Residential (9)	5	245	155	0.5	(7)	0.5	0.15
Hotel Function Area	67	250	200	0.5	60	2.2	0.50
Hotel/Motel Guest Room (9)	5	245	155	0.5	2800	0.5	0.15
Kitchen and Food Preparation	5	275	475	1.5	385	1.7	0.15
Laundry	10	250	250	3.0	385	0.9	0.15
Library - Reading Areas	20	250	200	1.5	120	1.2	0.15
Library - Stacks	10	250	200	1.5	120	1.5	0.15
Lobby - Hotel	10	250	250	0.5	120	~~2.2~~1.7	0.15
Lobby - Main Entry and Assembly	143	250	250	0.5	60	1.5	1.07
Lobby - Office Reception/Waiting	10	250	250	0.5	120	1.1	0.15
Locker and Dressing Room	20	255	475	0.5	385	~~0.9~~0.8	0.15
Mall, Arcade and Atrium	33	250	250	0.5	120	1.2	0.25
Medical and Clinical Care	10	250	200	1.5	160	1.4	0.15
Office	10	250	200	1.5	120	1.3	0.15
Police Station and Fire Station	10	250	200	1.5	120	0.9	0.15
Religious Worship	143	245	105	0.5	60	2.1	1.07
Retail Sales and Wholesale Showroom	33	250	200	1.0	120	2.0	0.25
Smoking Lounge	67	275	275	0.5	120	1.1	1.50
Theater (Motion Picture)	143	245	105	0.5	60	0.9	1.07
Theater (Performance)	143	245	105	0.5	60	1.4	1.07
Unknown	10	250	200	1.0	120	0.8	0.15

(1) Subcategories of these suboccupancies are described in Section 2.3.1.1 (Occupancy Types) of this manual.
(2) Values taken from the 1994 Uniform Building Code, Table No. 10-A. Full value for design conditions. Full year operational schedules reduce these values by up to 50% for compliance simulations and full year test simulations.
(3) From Table 3, p. 28.8, ASHRAE 1997 Handbook of Fundamentals.
(4) From Lawrence Berkeley Laboratory study. This value is fixed and includes all equipment that are plugged into receptacle outlets.

Notes for Table 2-2 (continued)

(5) From Table 1-N of the Standards for the applicable occupancy. ACMs must use this value for the standard building design when lighting compliance is performed for the zone or area in question.
(6) Developed from Section 121 and Table 1-F of the Standards.
(7) Refer to residential water heating method.
(8) The use of this occupancy category is an exceptional condition that must appear on the exceptional conditions checklist and thus requires special justification and documentation and independent verification by the local enforcement agency.
(9) For hotel/motel guest rooms and high-rise residential spaces all these values are fixed and are the same for both the proposed design and the standard design. ACMs must ignore user inputs that modify these assumptions for these two occupancies.

HVAC

2.4.2.9 Efficiency of Cooling Equipment Included in Built-up Systems

Description:	ACMs must require the user to input: (1) the type of central cooling plant equipment proposed (e.g. open centrifugal, open reciprocating, water chiller, direct expansion, etc.); (2) the number of central cooling units and the capacity of each unit; (3) the efficiency of each central cooling unit; and (4) the type of refrigerant to be used in each central cooling unit. ACMs shall not accept user-defined performance curves for any equipment except for electric chillers.
DOE Keyword:	COOLING-EIR
Input Type:	Default
Tradeoffs:	Yes
Modeling Rules for Proposed Design:	The ACM shall require the user to input efficiency descriptors at ARI test conditions for all equipment documented in plans and specifications for the building.
Default:	Minimum efficiency as specified in the Appliance Efficiency Regulations or Tables 1-C1 through 1-C7 of the Building Energy Efficiency Standards
Modeling Rules for Reference Design (New):	Based on the capacity and type of chiller(s) the reference method assigns the EER of each unit of the standard design according to the applicable requirements of the Appliance Efficiency Standards or the Standards.
Modeling Rules for Reference Design (Existing Unchanged & Altered Existing):	ACMs shall use the EER and the ARI fan power of the existing system.

2.4.2.11 Heating Efficiency of Heat Pumps not Covered by DOE Standards

Description: ACMs shall require the user to input the COP for all packaged heat pump equipment with fans that are not covered by DOE appliance standards.

ACMs shall also require the user to input the net heating capacity, $HCAP_a$, at ARI conditions for all equipment.

The reference method calculates the electrical heating input ratio, HIR, according Equation 2.4.8.

DOE Keyword: HEATING-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors as they occur in the construction documents.

Default: Minimum COP as specified in <u>either</u> the Appliance Efficiency Regulations <u>or Table 1-C2 of the Building Energy Efficiency Standards</u>

Modeling Rules for Reference Design (New): For the reference method, the HIR of each unit in the standard design is determined according to the applicable requirements of the Appliance Efficiency Standards or the Standards.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the COP and the ARI fan power of the existing system.

2.4.2.13 Heading Efficiency Fan Type Central Furnaces not Covered by DOE Standards

Description: The ACM shall require the user to input the steady state efficiency, or the HIR, of each furnace for each furnace's rated capacity.

DOE Keyword: HEATING-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors as they occur in the construction documents.

Default: Minimum COP as specified in either the Appliance Efficiency Regulations or Table 1-C5 of the Building Energy Efficiency Standards

Modeling Rules for Reference Design (New): The standard design shall assign the HIR of each unit according to the applicable requirements of the Standards.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

2.4.2.15 Efficiency of Boilers not Covered by DOE Standards

Description: ACMs must require the user to input: (1) the type of central boiler proposed (steam or water, forced or induced draft, etc); (2) the number of central boilers and the capacity of each unit; (3) the heating input ratio of each boiler; and (4) the type of primary fuel used in each boiler. ACMs shall use the same boiler part-load curve for the proposed and standard designs. The reference method uses the DOE 2.1E default part-load curves for boilers.

DOE Keyword: BOILER-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors at required testing conditions for all equipment documented in the plans and specifications for the building and shall model all combustion air fans as input by the user.

Default: Minimum AFUE as specified in either the Appliance Efficiency Regulations or or efficiency as specified in Table 1-C6 of the Building Energy Efficiency Standards

Modeling Rules for Reference Design (New): The standard design shall use a boiler or boilers with an AFUE as specified in either the Appliance Efficiency Regulations or efficiency as specified in Table 1-C6 of the Building Energy Efficiency Standards ~~HIR of 1.25~~ in the reference method.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

2.4.2.24 Air Economizers

Description: The reference method is capable of simulating an economizer that: (1) modulates outside air and return rates to supply up to 100% of design supply air quantity as outside air; and, (2) modulates to a fixed position at which the minimum ventilation air is supplied when the economizer is not in operation.

The reference method will simulate at least two types of economizers and all ACMs must receive input for these two types of economizers:

1. *Integrated*. The economizer is capable of providing partial cooling, even when additional mechanical cooling is required to meet the remainder of the cooling load. The economizer is shut off when outside air temperature or enthalpy is greater than a fixed setpoint.

2. *Nonintegrated/fixed set point.* This strategy allows only the economizer to operate below a fixed outside air temperature set point. Above that set point, only the compressor can provide cooling.

DOE Keyword: ECONO-LIMIT
ECONO-LOCKOUT
ECONO-LOW-LIMIT

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall allow the user to input either an *integrated* or *non-integrated* economizer as described above as it occurs in the construction documents. The ACM shall require the user to input the ODB set point.

Default: No Economizer

Modeling Rules for Reference Design (New): The standard design shall assume an *integrated* air economizer, available for cooling any time ODB < ~~75~~T_{limit}, on systems 1, 2, 3 and 4 (See ***Standard Design Systems Types***) when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm. T_{limit} shall be set to 75°F for climate zones 1, 2, 3, 5, 11, 13, 14, 15 & 16. T_{limit} shall be set to 70°F for climate zones 4, 6, 7, 8, 9, 10 & 12. The ACM shall not assume economizers on any system serving high-rise residential and hotel/motel guest room occupancies.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): All ACMs must model existing economizers as they occur in the existing building.

2.5.2.2 Water Heaters not Covered by DOE Appliance Standards

Description: ACMs must require the user to enter fuel type, input, volume, recovery efficiency or thermal efficiency, standby loss and quantity for all storage type water heaters that are not covered by DOE appliance standards.

DOE Keyword: DHW-TYPE
DHW-SIZE
DHW-HEAT-RATE
DHW-EIR
DHW-EIR-FT
DHW-EIR-FPLR
DHW-LOSS

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The proposed design shall assume fuel type, input, volume, recovery efficiency or thermal efficiency, standby loss and quantity as input by the user and as shown on the construction documents for the building.

Modeling Rules for Reference Design (All): The standard design shall assume fuel type, input, volume and quantity that are identical to the proposed design. The standard design shall assume recovery efficiency or thermal efficiency and standby loss ~~according to~~ as specified in either the Appliance Efficiency Regulations or Table 1-C11 of the Building Energy Efficiency Standards~~the applicable minimum requirements of Title 24, Part 1.~~

3.5.2.2 Absorption Cooling Equipment

Description: ACMs may model heat operated (absorption) cooling equipment with the following features:

- *One-stage absorption*. Heat operated water chiller. With this option, the ACM must account for absorber and refrigerant pump energy and purge cycle.
- *Two-stage absorption.* Heat operated water chiller using two stage or double effect concentrator. With this option, the ACM must account for absorber and refrigerant pump energy and purge cycle.
- *Economizer.* For absorption chiller, absorber solution flow to the concentrator is modulated as a function of load.
- *Steam fired.* Absorption chiller uses steam as the heat source.
- *Hot water fired.* Absorption chiller uses hot water as the heat source.
- *Direct fired.* Absorption chiller uses fossil fuel as heat source.

DOE Keyword: PLANT-EQUIPMENT
ABSOR1-CHLR
ABSOR2-CHLR
ABSORG-CHLR

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall model absorption equipment in the proposed design as input by the user according to the plans and specifications for the building. The ACM shall use performance relationships according to the DOE 2.1 default equipment curves.

Modeling Rules for Reference Design (New): ACMs shall determine the standard design according to the requirements of the Required Systems and Plant Capabilities and Figure 2-1. <u>The efficiency of the absorption chiller shall be as specified in Table 1-C3 of the Building Energy Efficiency Standards</u>

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall model the existing system as it occurs in the existing building. If the permit involves alterations, ACMs shall model the system before alterations.

Air Distribution Ducts

Figure 2-2a: System #1 and System #2 Descriptions	
System Description:	Packaged Single Zone with Gas Furnace/Electric Air Conditioning (#1) or Heat Pump (#2)
Supply Fan Power:	See Section 2.4.2.22
Supply Fan Control:	Constant volume
Min Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 55
Cooling System:	Direct expansion (DX)
Cooling Efficiency:	Minimum SEER or EER based on equipment type and output capacity of proposed unit(s). Adjusted EER is calculated to account for supply fan energy.
Maximum Supply Temp:	$85 \leq T \leq 110$ DEFAULT: 100
Heating System:	Gas furnace (#1) or heat pump (#2)
Heating Efficiency:	Minimum AFUE, Thermal Efficiency, COP or HSPF based on equipment type and output capacity of proposed unit(s).
Economizer:	Integrated dry-bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm
Ducts	For ducts installed in spaces between ceiling and roof, the duct system efficiency shall be as described in Section 4.3.4

2.4.2.7 Cooling Efficiency of DOE Covered Air Conditioners

Description: ACMs must require the user to input the SEER (seasonal energy efficiency ratio) of any DOE-covered consumer product. ACMs must allow the user to input the EER (energy efficiency ratio), however the ACM must not require this input for HVAC equipment that is covered by the U.S. DOE appliance standards.

ACMs must also use the ARI net cooling capacity input by the user, as required by this chapter, and the ARI tested fan power and part load capacity as calculated according to this chapter. These three values are also necessary to model efficiency of DOE-covered consumer products.

Modeling of SEER is achieved through accounting for the Electrical Input Ratio, EIR, and total system cooling capacity as functions of Outside Dry-Bulb (ODB) and Coil Entering Wet-Bulb (WB) temperatures, and through accounting for duct efficiency impacts on EIR.

The reference method is based on a created performance curve, similar to the DOE 2.1 curve COOL-EIR-FT, using the following points for WB, ODB and N_{eir}, respectively. This new curve is given below in terms of the reference computer program curve-fit instruction. For single-zone systems with ducts in buffer spaces for which the verified sealed duct option has been elected, the COOL-EIR-SEER shall be divided by the seasonal distribution efficiency calculated with Equation 4.17 in Appendix G.

COOL-EIR-SEER = CURVE-FIT
TYPE = BI-QUADRATIC
DATA = (67,95,1.0)
(67,82,N_{eirb})

(67,110,1.174)
(67,105,1.113)
(67,70,$N_{eir70/67adj}$)
(80,95,0.897)
(50,95,1.070) ..

where N_{eirb} and $N_{eir70/67adj}$ are calculated as follows:

1. ACMs must first calculate an EER_b from the following equation:

$$EER_b = \frac{SEER}{1 - 0.5 \times C_d}$$

Equation 2.4.1

where:

EER_b = Energy Efficiency Ratio at DOE part-load conditions. [Btuh/watt]

C_d = Cyclical degradation coefficient at DOE part-load conditions

2. If the EER is not input, calculate EER from the following equation:

$$EER = 0.855 \times EER_b$$

Equation 2.4.2

3. Calculate the electrical input ratio, EIR_a, at ARI conditions according to the following equation:

$$EIR_a = \frac{(CAP_a / EER) - ARIFanPower}{(CAP_a / 3.413) + ARIFanPower}$$

Equation 2.4.3

ARI Fan Power = The power [watts] used by the supply fan for the purpose of performing ARI, CEC and DOE approved tests (See ***ARI Fan Power***.)

CAP_a = The net cooling capacity at ARI conditions of 95 outside dry-bulb(ODB) and 67 coil entering wet-bulb (WB) [Btuh]

4. Calculate the electrical input ratio, EIR_b, at ARI part-load conditions according to the following equation:

$$EIR_b = \frac{(CAP_b / EER_b) - ARIFanPower}{(CAP_b / 3.413) + ARIFanPower}$$

Equation 2.4.4

where:

EER_b = From Equation 2.4.1 above. [Btuh/watts]

EIR_b = The electrical input ratio [unitless], or cooling electrical efficiency of the piece of equipment at ARI part-load conditions

CAP_b = The net cooling capacity [Btuh] at ARI part-load conditions (82 ODB and 67 WB), given by the following equation:

$$CAP_b = 1.07 \times CAP_a$$

Equation 2.4.5

where

CAP_a= The net cooling capacity [Btuh] at ARI conditions of 95 outside dry-bulb (ODB) and 67 coil entering wet-bulb (WB)

5. Normalize EIR_b based on ARI conditions, 95 outside dry-bulb (ODB):

   $N_{eirb}= EIR_b/EIR_a$ [unitless]

6. Calculate $N_{eir70/67adj}$ according to the following equation:

   $N_{eir70/67adj} = 0.876 \times N_{eirb}$ [unitless]

For heat pumps, the reference method uses performance curves based on the ratio of the COPs and CAPACITIES at 47^{o}F and at 17^{o}F (COP_{47}, COP_{17}, CAP_{47}, CAP_{17}) and creates new performance curves, similar to the DOE 2.1 COOL-EIR-FT and COOL-CAP-FT, using the following points for ODB and the COPs and CAPACITIES at these temperatures. <u>For single-zone systems with ducts in buffer spaces for which the verified sealed duct option has been elected, the HP-EIR-FT shall be divided by the seasonal distribution efficiencies calculated with Equation 4.17 in Appendix G for both the standard and proposed building.</u>

HP-EIR-FT = CURVE-FIT
TYPE = CUBIC
DATA =(67,0.856)
(57,0.919)
(47,1.000)

$(17, COP_{47}/COP_{17})$
$(7, 1.266 \times COP_{47}/COP_{17})$
(-13, 3.428) ..

HP-CAP-FT = CURVE-FIT
TYPE = CUBIC
DATA =(67,1.337)
(57,1.175)
(47,1.000)
$(17, CAP_{17}/CAP_{47})$
$(7, 0.702 \times CAP_{17}/CAP_{47})$
(-13, 0.153) ..

DOE Keyword: COOLING-EIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall require users to input a value for SEER and shall allow users to input a value for EER. ACMs shall use 0.03 for the cyclical degradation coefficient C_d. The reference method uses user input values to generate the required performance curves for the proposed design.

Default: Minimum SEER and EER as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): The ACM shall assign standard design performance data for the above functions according to the following criteria:

a) If the proposed design system is a *single package* unit according to the CEC Appliance Efficiency Standards, the standard design shall use an EER of 8.6, an SEER of 9.9 and a C_d of 0.03 to develop the required performance curves.

b) If the proposed design system is a *split system* according to the CEC Appliance Efficiency Standards, the standard design shall use an EER of 8.7, an SEER of 10.0 and a C_d of 0.03 to develop the required performance curves.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): The ACM shall assign standard design performance data for the above functions according to the following criteria:

a) If the existing system is a *single package* unit according to the CEC Appliance Efficiency Standards, the standard design shall use the EER or the SEER of the existing system and a C_d of 0.03 to develop the required performance curves.

b) If the existing system is a *split system* according to the CEC Appliance Efficiency Standards, the standard design shall use the EER or the SEER of the existing system and a C_d of 0.03 to develop the required performance curves.

The ACM shall use the ARI fan power of the existing system.

2.4.2.8 Cooling Efficiency of Packaged Equipment not Covered by DOE Appliance Standards

Description: ACMs shall require the user to input the EER for all packaged cooling equipment that are not covered by DOE appliance standards.

ACMs shall also require the user to input the net cooling capacity, CAPa, at ARI conditions for all cooling equipment.

For equipment where supply fan energy is included in the calculation of EER and CAPa, the reference method shall calculate the electrical input ratio, EIR, according to Equation 2.4.4.
For single-zone systems with ducts in buffer spaces for which the verified sealed duct option has been elected, the COOL-EIR shall be divided by the seasonal distribution efficiencies calculated with Equation 4.17 in Appendix G for both the standard and proposed building.

DOE Keyword: COOLING-EIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors at ARI conditions for all equipment documented in the plans and specifications for the building.

Default: Minimum EER as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): For the reference method, the standard design shall assign the EER and EIR of each unit according to the applicable requirements of the Appliance Efficiency Standards or the Standards. The EIR of the equipment will be based on the proposed system with an EER that meets the applicable requirements of the Standards but has the same cooling capacity and ARI fan power as the unit selected for the proposed design.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall use the EER, EIR, and the ARI fan power of the existing system. The EIR of the existing equipment must be based on the EER and the ARI fan power of the existing system.

2.4.2.10 Heating Efficiency of DOE Covered Heat Pumps

Description: ACMs must require the user to input: (1) the Heating Seasonal Performance Factor (HSPF); (2) the heating capacity at 47 ODB; and, (3) the system configuration, either *single package* unit or *split system* for DOE covered heat pumps.

The reference method calculates an equivalent Coefficient Of Performance (COP) according to the following:

a) For *single package* units:

$$COP = (0.2778 \times HSPF + 0.9667)$$

Equation 2.4.6a

b) For *split systems*:

$$COP = (0.4813 \times HSPF - 0.2606)$$

Equation 2.4.6b

The reference method will calculate the total heating capacity at ARI conditions, $HCAP_{atot}$ of the heat pump according to the following equation:

$$HCAP_{atot} = HCAP_a - (3.413 \times ARIFanPower)$$

Equation 2.4.7

where the total capacity, $HCAP_{atot}$ is given in Btu per hour [Btuh] and ARIFanPower is rated in watts.

The reference method calculates the electrical heating input ratio, HIR, according to the following equation:

$$HIR = \frac{[HCAP_a / (COP \times 3.413)] - ARIFanPower}{(HCAP_a / 3.413) - ARIFanPower}$$

Equation 2.4.8

<u>For single-zone systems with ducts in buffer spaces for which the verified sealed duct option has been elected, the HEATING-EIR shall be divided by the seasonal distribution efficiencies calculated with Equation 4.17 in Appendix G for both the standard and proposed building.</u>

DOE Keyword: HEATING-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input all required data, as it occurs in the construction documents.

Default: Minimum COP as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): The reference method and all ACMs shall assign a COP of 2.8 to standard design *single package* units and 3.0 to standard design *split systems*.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall use the COP and the ARI fan power of the existing system.

2.4.2.11 Heating Efficiency of Heat Pumps not Covered by DOE Standards

Description: ACMs shall require the user to input the COP for all packaged heat pump equipment with fans that are not covered by DOE appliance standards.

ACMs shall also require the user to input the net heating capacity, $HCAP_a$, at ARI conditions for all equipment.

The reference method calculates the electrical heating input ratio, HIR, according Equation 2.4.8.
For single-zone systems with ducts in buffer spaces for which the verified sealed duct option has been elected, the HEATING-EIR shall be divided by the seasonal distribution efficiencies calculated with Equation 4.17 in Appendix G for both the standard and proposed building.

DOE Keyword: HEATING-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors as they occur in the construction documents.

Default: Minimum COP as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): For the reference method, the HIR of each unit in the standard design is determined according to the applicable requirements of the Appliance Efficiency Standards or the Standards.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the COP and the ARI fan power of the existing system.

2.4.2.12 Heating Efficiency of DOE Covered Fan Type Central Furnaces

Description: ACMs shall require the user to input: (1) the AFUE; (2) the heating capacity; and (3) the system configuration for all DOE covered fan type central furnaces.

The reference method calculates an equivalent heating input ratio, HIR, according to the following:

a) For *single package* units:

$$HIR = (0.005163 \times AFUE + 0.4033)^{-1}$$

Equation 2.4.9a

b) For *split systems* with AFUEs not greater than 83.5:

$$HIR = (0.002907 \times AFUE + 0.5787)^{-1}$$

Equation 2.4.9b

c) For *split systems* with AFUEs greater than 83.5:

$$HIR = (0.011116 \times AFUE - 0.098185)^{-1}$$

Equation 2.4.9c

<u>For single-zone systems with ducts in buffer spaces for which the verified sealed duct option has been elected, the HEATING-EIR shall be divided by the seasonal efficiencies calculated with Equation 4.17 in Appendix G for both the standard and proposed building.</u>

DOE Keyword: HEATING-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall require the user to input the AFUE of each DOE covered central furnace.

Default: Minimum AFUE as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): The reference method assigns an HIR of 1.24 to all standard design heating systems when a fan-type central furnace is the proposed heating system.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

2.4.2.13 Heating Efficiency Fan Type Central Furnaces not Covered by DOE Standards

Description: The ACM shall require the user to input the steady state efficiency, or the HIR, of each furnace for each furnace's rated capacity.
For single-zone systems with ducts in buffer spaces for which the verified sealed duct option has been elected, the HEATING-EIR shall be divided by the seasonal distribution efficiencies calculated with Equation 4.17 in Appendix G for both the standard and proposed building.

DOE Keyword: HEATING-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors as they occur in the construction documents.

Default: Minimum COP as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): The standard design shall assign the HIR of each unit according to the applicable requirements of the Standards.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

ADD

2.4.2.35 HVAC Distribution Efficiency of Packaged Equipment

Description: **ACMs shall be able to determine the efficiency of ducts in the unconditioned spaces between insulated ceilings and roofs.**

ACMs shall require the user to enter the duct insulation R-value, the number of building stories, and whether or not the ducts will be sealed and tested for reduced duct leakage.
ACMs shall be able to reproduce the duct efficiencies in Appendix H

DOE Keyword: None. Duct efficiency divisors for COOLING-EIR, COOLING-EIR-SEER and HEATING-HIR will be calculated by means of the equations in Appendix G.

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input duct R-value, the number of building stories and whether or not credit for reduced duct leakage will be claimed and tested.

Default: Duct R-value of 4.2 [h^{o}F ft^{2}/Btu] and duct leakage of 22% of fan flow. Number of stories is defaulted to one (1).

Modeling Rules for Reference Design (New): The Reference Design shall assume the default values for the duct efficiency inputs (Duct R-value = 4.2, Duct Leakage = 22%) except that the number of stories shall be the same as for the Proposed Design.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall model the same distribution system for the Reference Design as for the Proposed Design.

MODIFY
Section 2.7.1 Add to list for PERF-1 on page 125
…….

- Variable speed drive fans
- Other high efficiency fan drive motors
- Verified sealed ducts in ceiling/roof spaces
- Any optional capabilities used

4.3.3.28 Duct Efficiency Calculation

Description: The ACM Compliance Documentation shall describe the parameters that the user must enter to describe the air distribution system when Chapter 7 and Appendix G are used in conjunction with verified duct sealing.

5.2.10 HVAC Distribution Efficiency Tests

Description: ACM duct efficiency calculations shall match the values shown in Appendix H

Chapter 7: Non-Residential Duct Installation Verification And Diagnostic Testing Using Home Energy Rating Systems (HERS)

Verified Duct Efficiency Improvements

The Commission has approved algorithms and procedures for determining duct and HVAC distribution efficiency for non-residential single-zone individual packaged equipment serving 5000 ft^2 or less via ductwork in the space between an insulated ceiling and the roof . Details of the energy efficiency calculations are presented in Appendix G.

There are two calculation procedures to determine seasonal air distribution efficiency using either: 1) default input assumptions, or 2) diagnostic measurement values. Air distribution efficiencies for heating and cooling shall be calculated separately. The ACM shall require the user to choose values for the following parameters to calculate seasonal duct efficiencies: duct insulation level and duct leakage level. The ACM shall use the defaults shown in [brackets] for the Standard Design and for the Proposed Design when the user does not enter a specific value for these parameters.:

1. Insulation level of ducts [R 4.2]
2. The leakage level of the duct system [22% of fan flow]. Two values are possible: the default or 8% of fan flow if measured and verified at no more than 6% of fan flow.

When any duct efficiency credit is claimed beyond the default assumptions that requires diagnostic testing or verification by a HERS rater or the local enforcement agency, i.e. when non-default values (except HVAC equipment capacities) are used to determine duct efficiency, the leaks in the air distribution system connections shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands and this requirement must be specified in the *Special Features and Modeling Assumptions* listings and the *HERS Required Verification* listings on the MECH-1. MECH-4 and Certificate of Field Verification and Diagnostic Testing (MECH-5).

The ACM shall automatically use the following values from the description of the *Proposed Design* when calculating the distribution system efficiency:

- Number of stories
- Building Conditioned Floor Area
- Building Volume
- Outdoor summer and winter design temperatures for each climate zone

When more than one HVAC system serves the building, the HVAC distribution efficiency is determined for each system and a conditioned floor area-weighted average seasonal efficiency is determined based on the inputs for each of the systems.

When an existing HVAC system is extended to serve an addition, the default assumptions for duct and HVAC distribution efficiency must be used for both the *Proposed Design* and the *Standard Design*. However, when a new, high efficiency HVAC distribution system is used to serve the addition or the addition and the existing building, that system may be modeled to receive energy credit subject to diagnostic testing and verification of proper installation by a HERS rater.

California Home Energy Rating Systems

The Commission is required to regulate home energy rating system (HERS) providers in California. These regulations appear in the California Code of Regulations, Title 20, Chapter 4, Article 8, Sections 1670-1676). Approved HERS providers are authorized to certify raters and maintain quality control over ratings. Ratings are based on visual inspection and diagnostic testing of the physical characteristics and energy efficiency features of buildings, as constructed.

When compliance documentation indicates field verification and diagnostic testing of specific energy efficiency improvements as a condition for those improvements to qualify for Title 24 compliance credit, an approved HERS provider and certified HERS rater shall be used to conduct the field verification and diagnostic testing. HERS providers and raters shall be considered special inspectors by building departments, and shall demonstrate competence, to the satisfaction of the building official, for the visual inspections and diagnostic testing. The HERS provider and rater shall be independent entities from the builder or subcontractor installer of the energy efficiency improvements being tested and verified, and shall have no financial interest in the installation of the improvements

HERS Required Verification and Diagnostic Testing

HERS diagnostic testing and field verification is required for compliance credit or requirements for:

- duct air sealing
- augmented duct insulation

For compliance credit to be claimed for these features, they shall be listed as *HERS Verification Required* features on the *Performance Certificate of Compliance* (PERF-1) and the *Mechanical Compliance Summary* (MECH-1), and *Mechanical Distribution Summary* (Certificate of Field Verification and Diagnostic Testing (MECH-5)). Such verification constitutes "eligibility and installation criteria" for these features. Field verified and diagnostically tested features must be described in the *Compliance Supplement*.

Installer Certification

When compliance or compliance credit has been claimed for duct sealing, builder employees or subcontractors shall:

- complete diagnostic testing, and
- certify on the Certificate of Field Verification and Diagnostic Testing (MECH-5) the diagnostic test results and that the work meets the requirements for compliance credit.

When compliance credit has been claimed for duct insulation levels beyond those covered by default assumptions, builder employees or subcontractors shall:

- record on the CF-6R the duct R-value in each duct location

Installer certifications are required for each and every building.

HERS Verification Procedures

HERS field verification and diagnostic testing shall be completed for each building. Field verification and diagnostic testing for compliance credit for duct sealing shall use the diagnostic duct leakage from fan pressurization of ducts in Section 4.3.8.2 of Appendix G.

Responsibilities and Documentation

Builder

Builder employees or subcontractors responsible for completing either diagnostic testing, visual inspection or verification as specified in Section 7.3 shall certify the diagnostic testing results and that the work meets the requirements for compliance credit on the Certificate of Field Verification and Diagnostic Testing (MECH-5).

The builder shall provide the HERS provider with the identifying location of the building to receive diagnostic testing and the expected date that testing may begin. The builder shall provide the HERS provider a copy of the Certificate of Field

Verification and Diagnostic Testing (MECH-5) signed by the builder employees or sub-contractors certifying that diagnostic testing and installation meet the requirements for compliance credit.

The builder shall provide a Certificate of Field Verification and Diagnostic Testing (MECH-5) signed and dated by the HERS rater to the building official in conjunction with requests for final inspection for each building.

HERS Provider and Rater

The HERS provider shall maintain records of all buildings tested, corrective actions taken, and copies of all Certificate of Field Verification and Diagnostic Testing (MECH-5) forms for a period of five years.

The HERS rater providing the diagnostic testing and verification shall sign and date a Certificate of Field Verification and Diagnostic Testing (MECH-5) form certifying that he/she has verified that the requirements for compliance credit have been met. The HERS rater shall provide this certificate to the builder and the HERS provider.
The HERS rater shall not sign a Certificate of Field Verification and Diagnostic Testing (MECH-5) form for a building that does not have a Certificate of Field Verification and Diagnostic Testing (MECH-5) form signed by the installer as required in Sections 7.4 and 7.6.1.

Building Department

The building department at its discretion may require independent testing and field verification in conjunction with the building department's required inspections, and/or observe the diagnostic testing and field verification performed by builder employees or subcontractors and the certified HERS rater in conjunction with the building department's required inspections to corroborate the results documented in installer certifications, and in the Certificate of Field Verification and Diagnostic Testing (MECH-5) form.

For buildings that have used a compliance alternative that requires field verification and diagnostic testing, the building department shall not approve a building for occupancy until the building department has received from the builder a Certificate of Field Verification and Diagnostic Testing (MECH-5) form that has been signed and dated by the HERS rater.

Appendix G

Standard Procedure for Determining the Seasonal Energy Efficiencies of Single-Zone Non-Residential Air Distribution Systems in the Space Between an Insulated Ceiling and the Roof

1.0 Introduction

This appendix describes the measurement and calculation methods for determining air distribution system efficiency for single-zone non-residential air distribution systems in the space between an insulated ceiling and the roof.

2.0 Definitions

***aerosol sealant closure system**:* A method of sealing leaks by blowing aerosolized sealant particles into the duct system and which must include minute-by-minute documentation of the sealing process.

floor area :The floor area of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces enclosing the conditioned space.

delivery effectiveness :The ratio of the thermal energy delivered to the conditioned space and the thermal energy entering the distribution system at the equipment heat exchanger.

distribution system efficiency :The ratio of the thermal energy consumed by the equipment with the distribution system to the energy consumed if the distribution system had no losses or impact on the equipment or building loads.

equipment efficiency :The ratio between the thermal energy entering the distribution system at the equipment heat exchanger and the energy being consumed by the equipment.

equipment factor : F_{equip} is the ratio of the equipment efficiency including the effects of the distribution system to the equipment efficiency of the equipment in isolation.

***fan flowmeter device**:* A device used to measure air flow rates under a range of test pressure differences.

***flowhood*:** A device used to capture and measure the airflow at a register.

load factor : F_{load} is the ratio of the building energy load without including distribution effects to the load including distribution system effects.

pressure pan : a device used to seal individual forced air system registers and to measure the static pressure from the register.

radiant barrier : a surface of low emissivity (less than 0.05) placed inside an attic or roof space to reduce radiant heat transfer.

recovery factor : F_{recov} is the fraction of energy lost from the distribution system that enters the conditioned space.

thermal regain: The fraction of delivery system losses that are returned to the building.

3.0 Nomenclature

a_r = duct leakage factor (1-return eakage) for return ducts
a_s = duct leakage factor (1-supply leakage)p for supply ducts
A_{floor} = conditioned floor area of building , ft^2
$A_{r,out}$ = surface area of return duct outside conditioned space ,ft^2
$A_{r,attic}$ = return duct area in attic , ft^2
$A_{r,base}$ = return duct area in basement , ft^2
$A_{r,crawl}$ = return duct area in crawlspace, ft^2
$A_{r,gar}$= return duct area inside garage, ft^2
$A_{s,out}$ = surface area of supply duct outside conditioned space,ft^2
$A_{s,attic}$ = supply duct area in attic , ft^2
$A_{s,base}$ = supply duct area in basement , ft^2
$A_{s,crawl}$ = supply duct area in crawlspace,ft^2
$A_{s,gar}$ = supply duct area inside garage, ft^2
$A_{s,in}$ = supply duct area inside conditioned space, ft^2
B_r = conduction fraction for return
B_s = conduction fraction for supply
DE = delivery effectiveness
DE_{design} = design delivery effectiveness
$DE_{seasonal}$ = seasonal delivery effectiveness
E_{equip} = rate of energy exchanged between equipment and delivery system, Btu/hour
$F_{cycloss}$ = cyclic loss factor
F_{equip} = load factor for equipment
F_{flow} = load factor for fan flow effect on equipment efficiency
F_{leak} = fraction of system fan flow that leaks out of supply or return ducts
F_{load} = load factor for delivery system
F_{recov} = thermal loss recovery factor
F_{regain} = thermal regain factor
K_r = return duct surface area coefficient
K_s = supply duct surface area coefficient
N_{story} = number of stories of the building
P_{sp} = pressure difference between supply plenum and conditioned space [Pa]
P_{test} = test pressure for duct leakage [Pa]
Q_e = Flow through air handler fan at operating conditions, cfm
$Q_{total,25}$ = total duct leakage at 25 Pascal, cfm
R_r = thermal resistance of return duct, h ft^2 F/Btu
R_s = thermal resistance of supply duct, h ft^2 F/Btu
$T_{amb,r}$ = ambient temperature for return , F
$T_{amb,s}$ = ambient temperature for supply , F
T_{attic} = attic air temperature , F
T_{base} - return duct temperature in basement, F
T_{crawl} - return duct temperature in crawlspace,F
T_{design} = outdoor air design temperature , F
T_{ground} = ground temperature , F
T_{gar} = temperature of garage air , F
T_{in} = temperature of indoor air , F
T_{rp} = return plenum air temperature , F
$T_{seasonal}$ = outdoor air seasonal temperature, F
T_{sp} = supply plenum air temperature , F
ΔT_e = temperature rise across heat exchanger , F
ΔT_r = temperature difference between indoors and the ambient for the return , F
ΔT_s = temperature difference between indoors and the ambient for the supply,
$\eta_{dist,seasonal}$ = seasonal distribution system efficiency

4.0 Air Distribution Diagnostic Measurement and Default Assumptions

4.1 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

4.1.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes.

4.1.2 Fan Flow Measurements

All measurements of distribution fan flows shall be made with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ±5% reading or ±5 cfm whichever is greater.

4.1.3 Duct Leakage Measurements

The measurement of air flows during duct leakage testing shall have an accuracy of ±3% of measured flow using digital gauges.

All instrumentation used for fan flow and duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the above accuracy requirement. All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.

4.2 Apparatus

4.2.1 Duct Leakage

The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in Section 4.1.3.

4.3 Procedure

The following sections identify input values for building and HVAC system (including ducts) using either default or diagnostic information.

4.3.1 Building Information

The calculation procedure for determining air distribution efficiencies requires the following building information:

1. climate zone for the building,
2. conditioned floor area, and
3. number of stories,

4.3.1.1 Default Input

Using default values rather than diagnostic procedures produce relatively low air distribution-system efficiencies. Default values shall be obtained from following sections:

1. the location of the duct system in Section 4.3.4,
2. the surface area and insulation level of the ducts in Sections 4.3.3, 4.3.4 and 4.3.6,
3. the system fan flow in Section 4.3.7, and
4. the leakage of the duct system in Section 4.3.8.

4.3.2 Diagnostic Input

Diagnostic inputs are used for the calculation of improved duct efficiency. The diagnostics include observation of various duct characteristics and measurement of duct leakage and system fan flows as described in Sections 4.3.5 through 4.3.8. These observations and measurements replace those assumed as default values.

The diagnostic procedures include

- measure total duct system leakage as described in Section 4.3.8.
- Observe the insulation level for the supply (R_s) and return (R_r) ducts outside the conditioned space as described in Section 4.3.6.

4.3.3 Duct Surface Area

The supply-side and return-side duct surface areas shall be calculated separately. If the supply or return duct is located in more than one zone, the area of that duct in each zone shall be calculated separately. The duct surface area shall be determined using the following methods.

4.3.3.1 Duct Surface Area

4.3.3.1.1 Duct Surface Area

The duct surface area for supply and return shall be calculated as follows:
For supplies:

$$A_{s,total} = K_s \, A_{floor} \quad (4.1)$$

Where K_s (supply duct surface area coefficient) shall be 1 for one story buildings, 0.5 for two story buildings, and 0.33 for three-story buildings.

For returns:

$$A_{r,total} = K_r \, A_{floor} \quad (4.2)$$

Where K_r (return duct surface area coefficient) shall be 0.05 for one story building and 0.1 for two or more stories.

4.3.4 Duct Location

Ducts shall be considered to be in buffer spaces if they are in a space between an insulated ceiling and the roof, and that space is either a) vented to the outdoors, and/or b) insulated from the indoors.

4.3.5 Climate and Duct Ambient Conditions for Ducts in the Space Between an Insulated Ceiling and the Roof Duct ambient temperature for both heating and cooling shall be obtained from Table 4.2. Indoor dry-bulb (T_{in}) temperature for cooling is 78°F. The indoor dry-bulb temperature for heating is 70°F.

Table 4.2 Default Assumptions for Duct Ceiling/Roof Space Ambient Temperature		
Climate zone	Duct Ambient Temperature for Heating, $T_{heat,amb}$	Duct Ambient Temperature for Cooling, $T_{cool,amb}$
1	52.0	60.0
2	48.0	87.0
3	55.0	80.0
4	53.0	79.0
5	49.0	74.0
6	57.0	81.0
7	62.0	74.0
8	58.0	80.0
9	53.0	87.0
10	53.0	91.0
11	48.0	95.0
12	50.0	91.0
13	48.0	92.0
14	39.0	99.0
15	50.0	102.
16	32.0	80.0

4.3.6 Duct Wall Thermal Resistance

4.3.6.1 Default Duct Insulation R value
Default duct wall thermal resistance is R4.2. An air film resistance of 0.7 [h ft^2 ^oF/BTU] shall be added to the duct insulation R value to account for external and internal film resistance.

4.3.6.2 Diagnostic Duct Wall Thermal Resistance
Duct wall thermal resistance shall be determined from the manufacturer's specification observed during diagnostic inspection. If ducts with multiple R values are installed, the lowest duct R value shall be used. If a duct with a higher R value than 4.2 is installed, the R-value shall be clearly stated on the building plan and a visual inspection of the ducts must be performed to verify the insulation values. In case the space on top of the duct boot is limited and can not be inspected, the insulation R value within two feet of the boot to which the duct is connected may be excluded from the determination of the overall system R value.

4.3.7 System Fan Flow

4.3.7.1 Default Fan Flow
The default cooling fan flow with an air conditioner and for heating with a heat pump for **all climate zones** shall be calculated as follows:

$$Q_e = 1.25\ A_{floor} \quad (4.3)$$

4.3.8 Duct Leakage

4.3.8.1 Duct Leakage Factor for Delivery Effectiveness Calculations

Default duct leakage factors shall be obtained from Table 4.3, using the “not Tested” values.
Duct leakage factors shown in Table 4.3 shall be used in calculations of delivery effectiveness.

Table 4.3 Duct Leakage Factors

	Duct Leakage Diagnostic Test Performed using Section 4.3.8.2 Procedures	$a_s = a_r =$
Duct systems in buildings built prior to 2001	Not tested	0.86
Duct systems in buildings built after 2001	Not tested	0.89
Duct systems in buildings of all ages, System tested after HVAC system completion	(Q_{25}) Total leakage is less than 0.06 Q_e	0.96

4.3.8.2 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is used to quantify total leakage for the calculation of air distribution efficiency. To obtain the improved duct efficiency for sealing the duct system, a diagnostic leakage test as described in section 4.3.8.2.1 or 4.3.8.2.2 must be performed.

4.3.8.2.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

The total duct leakage shall be determined by pressurizing the ducts to 25 Pascals with all ceiling diffusers/grilles and HVAC equipment installed. The following procedure shall be used for the fan pressurization tests:

1. Seal all the supply and return registers, except for one return register or the system fan access.
2. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
3. Install a static pressure probe at a supply.
4. Adjust the fan flowmeter to produce a 25 Pascal (0.1 in water) pressure difference between the supply duct and the outside or the building space with the entry door open to the outside.
5. Record the flow through the flowmeter ($Q_{total,25}$) - this is the total duct leakage flow at 25 Pascals.

When the diagnostic leakage test is performed and the measured total duct leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in Table 4.3.

4.3.8.2.2 Diagnostic Duct Leakage Using An Aerosol Sealant Closure System

Same procedure as for other closure systems

Duct leakage in new construction may be determined by using diagnostic measurements at the rough-in building construction stage prior to installation of the interior finishing wall when using an aerosol sealant closure system. When using this measurement technique, additional verification (as described in section 4.3.8.2.2.3) of duct integrity shall be completed after the finishing wall has been installed. In addition, after the finishing wall is installed, spaces between the register boots and the wallboard shall be sealed. Cloth backed rubber adhesive duct tapes shall not be used to seal the space between the register boot and the wall board.

The duct leakage measurement at rough-in construction stage shall be performed using a fan pressurization device. The duct leakage shall be determined by pressurizing both the supply and return ducts to 25 Pa. The procedures in Sections 4.3.8.2.2.1 and 4.3.8.2.2.2 shall be used for measuring duct leakage before the interior finishing wall is installed.

4.4 Delivery Effectiveness (DE) Calculations

Seasonal delivery effectiveness shall be calculated using the seasonal design temperatures from Tables 4.2.

4.4.1 Calculation of Duct Zone Temperatures

The temperatures of the duct zones outside the conditioned space are determined in Section 4.3.5 for seasonal conditions for both heating and cooling.

For heating:

$$T_{amb,s} = T_{amb,r} = T_{amb,heat} \quad (4.8)$$

For cooling:

$$T_{amb,s} = T_{amb,r} = T_{amb,cool} \quad (4.9)$$

Where

Tamb,heat and Tamb,cool are determined from values in Table 4.2.

4.4.2 Seasonal Delivery Effectiveness (DE)

The supply and return conduction fractions, B_s and B_r, shall be calculated as follows:

$$B_s = \exp\left(\frac{-A_{s,out}}{1.08 Q_e \; R_s}\right) \quad (4.9)$$

$$B_r = \exp\left(\frac{-A_{r,out}}{1.08 \; Q_e \; R_r}\right) \quad (4.10)$$

The temperature difference across the heat exchanger in the following equation is used:
for heating:

$$\Delta T_e = 55 \quad (4.11)$$

for cooling:

$$\Delta T_e = -20 \quad (4.12)$$

The temperature difference between the building conditioned space and the ambient temperature surrounding the supply, ΔT_s, and return, ΔT_r, shall be calculated using the indoor and the duct ambient temperatures.

$$\Delta T_s = T_{in} - T_{amb,s} \quad (4.13)$$

$$\Delta T_r = T_{in} - T_{amb,r} \quad (4.14)$$

The seasonal delivery effectiveness for heating systems shall be calculated using:

$$DE_{seasonal} = a_s B_s - a_s B_s (1 - B_r a_r) \frac{\Delta T_r}{\Delta T_e} - a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e} \quad (4.15)$$

4.5 Seasonal Distribution System Efficiency

Seasonal distribution system efficiency shall be calculated using delivery effectiveness, equipment, load, and recovery factors calculated for seasonal conditions.

4.5.1 Equipment Efficiency Factor (F_{equip})

F_{equip} is 1.

4.5.2 Thermal Regain (F_{regain})

The reduction in building load due to regain of duct losses shall be calculated using the thermal regain factor. The default thermal regain factors are provided in Table 4.4.

Table 4.4 Thermal Regain Factors	
Supply Duct Location	**Thermal Regain Factor [F_{regain}]**
Ceiling/Roof Space	0.10

4.5.3 Recovery Factor (F_{recov})

The recovery factor, F_{recov}, is calculated based on the thermal regain factor, F_{regain}, and the duct losses without return leakage.

$$F_{recov} = 1 + F_{regain}\left(\frac{1 - a_s B_s + a_s B_s (1 - B_r)\dfrac{\Delta T_r}{\Delta T_e} + a_s (1 - B_s)\dfrac{\Delta T_s}{\Delta T_e}}{DE_{seasonal}}\right) \qquad (4.16)$$

4.5.4 Seasonal Distribution System Efficiency

The seasonal distribution system efficiency shall be calculated using the seasonal delivery effectiveness from section 4.4.2 or 4.4.3, the equipment efficiency factor from section 4.5.1, the load factor from section 4.5.3 and the thermal recovery factor from Section 4.5.4. Note that $DE_{seasonal}$, F_{equip}, F_{recov} must be calculated separately for cooling and heating conditions. Distribution system efficiency shall be determined using the following equation:

$$\eta_{dist,seasonal} = 0.98 \; DE_{seasonal} \; F_{equip} \; F_{recov} \qquad (4.17)$$

where 0.98 accounts for the energy losses from heating and cooling the duct thermal mass.

Appendix H – Seasonal Energy Efficiencies for Air Distribution Systems

Appendix H:

Seasonal Energy Efficiencies of Single-Zone Non-Residential Air Distribution Systems in the Space Between an Insulated Ceiling and the Roof in California Climate Zones

CASE CODE	Input Assumptions forNon-Residential Duct Systems Total duct Leakage,%	Supply duct R Value	Return duct R value
1001	22	4.2	4.2
1002	22	8	4.2
1003	22	4.2	8
1004	22	8	8
1005	8	4.2	4.2
1006	8	8	4.2
1007	8	4.2	8
1008	8	8	8

CASE	Climate Zone 1				Climate Zone 2			
CODE	1 Story		2 Story		1 Story		2 Story	
	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%
1001	0.756	0.810	0.785	0.812	0.743	0.674	0.773	0.702
1002	0.796	0.813	0.812	0.814	0.786	0.715	0.801	0.729
1003	0.758	0.810	0.788	0.812	0.745	0.676	0.777	0.706
1004	0.798	0.813	0.815	0.814	0.788	0.717	0.805	0.734
1005	0.825	0.866	0.856	0.869	0.815	0.744	0.848	0.775
1006	0.869	0.869	0.886	0.871	0.862	0.790	0.879	0.805
1007	0.827	0.866	0.860	0.869	0.818	0.746	0.852	0.780
1008	0.871	0.869	0.889	0.871	0.864	0.792	0.883	0.810
	Climate Zone 3				Climate Zone 4			
	1 Story		2 Story		1 Story		2 Story	
	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%
1001	0.766	0.730	0.794	0.755	0.759	0.738	0.788	0.763
1002	0.804	0.763	0.820	0.777	0.799	0.769	0.814	0.783
1003	0.767	0.731	0.796	0.756	0.761	0.738	0.791	0.763
1004	0.806	0.763	0.822	0.778	0.801	0.770	0.817	0.784
1005	0.832	0.786	0.863	0.813	0.827	0.792	0.858	0.818
1006	0.874	0.821	0.891	0.836	0.871	0.826	0.887	0.841
1007	0.833	0.786	0.865	0.814	0.829	0.792	0.862	0.819
1008	0.876	0.822	0.894	0.837	0.873	0.826	0.891	0.841

CASE CODE	Climate Zone 5				Climate Zone 6			
	1 Story		2 Story		1 Story		2 Story	
	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%
1001	0.747	0.760	0.776	0.779	0.772	0.722	0.800	0.747
1002	0.788	0.784	0.804	0.795	0.810	0.756	0.825	0.770
1003	0.748	0.760	0.779	0.779	0.773	0.723	0.802	0.749
1004	0.790	0.784	0.807	0.795	0.811	0.757	0.827	0.771
1005	0.818	0.813	0.850	0.834	0.837	0.780	0.867	0.807
1006	0.864	0.839	0.880	0.851	0.878	0.817	0.894	0.832
1007	0.820	0.813	0.854	0.834	0.838	0.781	0.869	0.809
1008	0.866	0.839	0.885	0.851	0.879	0.818	0.897	0.834
	Climate Zone 7				Climate Zone 8			
	1 Story		2 Story		1 Story		2 Story	
	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%
1001	0.788	0.760	0.815	0.779	0.775	0.752	0.803	0.770
1002	0.823	0.784	0.838	0.795	0.812	0.775	0.828	0.785
1003	0.788	0.760	0.816	0.779	0.776	0.752	0.805	0.770
1004	0.824	0.784	0.839	0.795	0.813	0.776	0.830	0.786
1005	0.848	0.813	0.878	0.834	0.839	0.809	0.869	0.829
1006	0.887	0.839	0.903	0.851	0.880	0.835	0.896	0.846
1007	0.849	0.813	0.879	0.834	0.840	0.810	0.871	0.830
1008	0.888	0.839	0.905	0.851	0.881	0.835	0.898	0.847
	Climate Zone 9				Climate Zone 10			
	1 Story		2 Story		1 Story		2 Story	
	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%
1001	0.759	0.702	0.788	0.723	0.759	0.674	0.788	0.696
1002	0.799	0.732	0.814	0.743	0.799	0.708	0.814	0.718
1003	0.761	0.704	0.791	0.726	0.761	0.676	0.791	0.700
1004	0.801	0.734	0.817	0.746	0.801	0.710	0.817	0.723
1005	0.827	0.775	0.858	0.798	0.827	0.756	0.858	0.780
1006	0.871	0.809	0.887	0.820	0.871	0.794	0.887	0.805
1007	0.829	0.777	0.862	0.802	0.829	0.759	0.862	0.785
1008	0.873	0.811	0.891	0.824	0.873	0.797	0.891	0.811
	Climate Zone 11				Climate Zone 12			
	1 Story		2 Story		1 Story		2 Story	
	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%
1001	0.743	0.645	0.773	0.669	0.750	0.674	0.779	0.696
1002	0.786	0.683	0.801	0.694	0.791	0.708	0.806	0.718
1003	0.745	0.648	0.777	0.675	0.751	0.676	0.782	0.700
1004	0.788	0.686	0.805	0.700	0.793	0.710	0.810	0.723
1005	0.815	0.737	0.848	0.762	0.820	0.756	0.852	0.780
1006	0.862	0.779	0.879	0.790	0.866	0.794	0.882	0.805
1007	0.818	0.740	0.852	0.769	0.822	0.759	0.856	0.785
1008	0.864	0.783	0.883	0.798	0.868	0.797	0.886	0.811

CASE CODE	Climate Zone 13				Climate Zone 14			
	1 Story		2 Story		1 Story		2 Story	
	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%
1001	0.743	0.667	0.773	0.689	0.715	0.617	0.746	0.642
1002	0.786	0.702	0.801	0.712	0.762	0.659	0.777	0.669
1003	0.745	0.669	0.777	0.694	0.718	0.621	0.752	0.649
1004	0.788	0.704	0.805	0.717	0.765	0.663	0.783	0.677
1005	0.815	0.751	0.848	0.776	0.794	0.717	0.828	0.745
1006	0.862	0.790	0.879	0.801	0.846	0.764	0.863	0.776
1007	0.818	0.754	0.852	0.781	0.797	0.721	0.835	0.753
1008	0.864	0.793	0.883	0.807	0.849	0.768	0.870	0.784
	Climate Zone 15				Climate Zone 16			
	1 Story		2 Story		1 Story		2 Story	
	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%	Heating,%	Cooling,%
1001	0.750	0.596	0.779	0.622	0.693	0.730	0.725	0.755
1002	0.791	0.640	0.806	0.651	0.743	0.763	0.759	0.777
1003	0.751	0.600	0.782	0.630	0.696	0.731	0.732	0.756
1004	0.793	0.645	0.810	0.660	0.747	0.763	0.766	0.778
1005	0.750	0.596	0.779	0.622	0.693	0.730	0.725	0.755
1006	0.791	0.640	0.806	0.651	0.743	0.763	0.759	0.777
1007	0.751	0.600	0.782	0.630	0.696	0.731	0.732	0.756
1008	0.868	0.758	0.886	0.775	0.838	0.822	0.859	0.837